

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)


REC'D 27 SEP 2005

Applicant's or agent's file reference P/2227.WO/CJW	FOR FURTHER ACTION		See Form PCT/IPEA416
International application No. PCT/EP2004/003010	International filing date (day/month/year) 22.03.2004	Priority date (day/month/year) 24.03.2003	
International Patent Classification (IPC) or national classification and IPC G01J9/02			
Applicant TSUNAMI PHOTONICS LTD et al.			

- This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
- This REPORT consists of a total of 7 sheets, including this cover sheet.
- This report is also accompanied by ANNEXES, comprising:
 - ☒ sent to the applicant and to the International Bureau) a total of 5 sheets, as follows:
 - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
 - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
 - ☐ (sent to the International Bureau only) a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

- This report contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

Date of submission of the demand 24.01.2005	Date of completion of this report 28.09.2005
Name and mailing address of the international preliminary examining authority:  European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer de Bakker, M Telephone No. +31 70 340-4759



**INTERNATIONAL PRELIMINARY REPORT
ON PATENTABILITY**

International application No.
PCT/EP2004/003010

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.
- ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
- ☐ international search (under Rules 12.3 and 23.1(b))
 - ☐ publication of the international application (under Rule 12.4)
 - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)
2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-14 as originally filed

Claims, Numbers

1-29 received on 26.01.2005 with letter of 24.01.2005

Drawings, Sheets

1/7-7/7 as originally filed

- ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/figs
- ☐ the sequence listing (*specify*):
- ☐ any table(s) related to sequence listing (*specify*):

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/figs
- ☐ the sequence listing (*specify*):
- ☐ any table(s) related to sequence listing (*specify*):

* If item 4 applies, some or all of these sheets may be marked "superseded."

**INTERNATIONAL PRELIMINARY REPORT
ON PATENTABILITY**

International application No.
PCT/EP2004/003010

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	1-29
	No: Claims	
Inventive step (IS)	Yes: Claims	1-29
	No: Claims	
Industrial applicability (IA)	Yes: Claims	1-29
	No: Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

**Reasoned statement with regard to novelty, inventive step or industrial applicability;
citations and explanations supporting such statement**

1 Reference is made to the following documents:

D1: WO 01/16569 A (KITCHER DANIEL JOHN ; BOOKHAM TECHNOLOGY PLC
(GB)) 8 March 2001

D2: GB 2 394 118 A (DONOHOE G ET AL) 14 April 2004

Document D2 has been cited by the applicant in the description.

Novelty

2 The present application meets the criteria of Article 33(1) PCT, because the subject-matter of **claims 1-29** is new in the sense of Article 33(2) PCT.

2.1 The document D1 is regarded as being the closest prior art to the subject-matter of **claim 1**, and shows (the references in parentheses applying to this document):

An optical wavelength meter for measuring an optical wavelength of an optical beam (page 2, lines 11-24) comprising:

- a) coarse optical filter means and first optical power measurement means for measuring output of the coarse optical filter means and second optical power measurement means for measuring an unfiltered reference beam for coarse wavelength measurement (page 9, lines 5-24; Figure 7);
- b) fine optical filter means comprising first and second periodic optical filters in quadrature and third and fourth optical power measurement means for measuring output of the first and second periodic optical filters in quadrature for fine wavelength measurement, respectively (page 10, line 23 - page 11, line 22);
- c) beam splitting means for splitting the optical beam between the unfiltered reference beam and the coarse and fine optical filter means (page 8, lines 7-14);
- e) processing means for determining the optical wavelength of the optical beam

from a predetermined transmissivity-wavelength relationship of the coarse filter and the first and second optical power measurement means for coarse wavelength measurement and from predetermined transmissivity-wavelength relationships of the first and second periodic optical filters and at least one of the third and fourth optical power measurement means for fine wavelength measurement (page 8, lines 4-6).

The subject-matter of **claim 1** differs from this known optical wavelength meter in that:

- b) the fine optical filters have a finesse of substantially 2 and a free spectral range of substantially 100 GHz, such that peaks and troughs of the first filter coincide with substantially linear ranges between peaks and troughs of the second filter;
- d) synchronized clock signal measurement means are provided for synchronized measurement of the output of the first, second, third and fourth optical power measurement means;

The subject-matter of **claim 1** is therefore new (Article 33(2) PCT).

2.2 It is mentioned here that **claim 7** (where the free spectral range of the fine optical filters is 50 GHz *instead of* 100 GHz), although drafted as a dependent claim, is in fact independent. The subject-matter of independent **claim 7** is new for the same reasons as laid out in paragraph 2.1 above.

2.3 Document D1 is also regarded as being the closest prior art to the subject-matter of independent method **claim 24**. The subject-matter of **claim 24** differs from this known method of determining wavelength (see also the citations given in paragraph 2.1 above) in that:

- e) the fine optical filters have a finesse of substantially 2 and a free spectral range of substantially 100 GHz, such that peaks and troughs of the first filter coincide with substantially linear ranges between peaks and troughs of the second filter;
- d) synchronized clock signal measurement means are used to read outputs from the first, second, third and fourth photodetector means;

- g) the fine filter with the greater sensitivity to wavelength is determined; and in that
- h) the wavelength of the optical beam is determined based on the photodetector output corresponding to the fine filter having the greater sensitivity.

The subject-matter of **claim 24** is therefore new (Article 33(2) PCT).

- 2.4 **Claims 1-23** are dependent on **claim 1** (or on **claim 7**) and as such also meet the requirements of the PCT with respect to novelty. The same holds for method **claims 25-29** that depend on **claim 24**.

Inventive Step

- 3 The present application meet the criteria of Article 33(1) PCT, because the subject-matter of **claims 1-34** involves an inventive step in the sense of Article 33(3) PCT.
- 3.1 The following three features form the contribution of **claim 1** over D1 (see paragraph 2.1 above):
- synchronized clock signal measurement means
 - a free spectral range (FSR) of substantially 100 GHz
 - a filter finesse of substantially 2

Synchronized clock measurements are regarded as a matter of normal design procedure in using a measurement systems with multiple sensors. Although not explicitly mentioned in D1, a skilled person when building a system with two or more sensors as described in D1 *would* synchronize the various measurements.

Further, in D1 no indication is revealed concerning the FSR of the filters that are used. As a reference, document D2 (cited by the applicant) is taken, where a similar wavelength meter is described. In D2, two fine optical filters are employed: one with a 5 GHz FSR and one with a 50 GHz FSR (as in **claim 7** of the current application). The FSR is a design parameter of the filter that a skilled person chooses according to the design criteria (such as required accuracy) for a wavelength meter. These sort of design considerations fall within the customary practice followed by skilled persons. There is no reason why a skilled person would not pick an FSR of 100 GHz (instead

of 50 Ghz) if this is required by the circumstances.

In conclusion, the finesse of substantially 2 is considered to be the true contribution of **claim 1** over D1.

- 3.2 The problem to be solved by the present invention may be regarded as: how to improve the accuracy of the wavelength meter of D1.
- 3.3 In D1, no figures for the finesse of the optical filters are given, but a direct indication can be found on page 5, line 9, where a Fabry-Perot filter is described with a mirror reflectivity of 0.33. The Fabry-Perot finesse (F) depends on mirror reflectivity (R) according to the well-known equation $F = 4R / (1-R)^2$. With $R=0.33$ this leads to a finesse of about 3, which is close to the finesse of **claim 1**. D1, however, proceeds to teach how the finesse can be improved (i.e. increased: see page 5, lines 13-24). In other words, according to D1, the finesse is preferably chosen larger than 3 (or even a high finesse is preferred according to the last paragraph on page 12 of D1). Although it can be deducted that a high finesse is not desirable since this leads to a poor resolution in the region between the filter peaks, D1 seems to be missing this point.

Defining an (optimum) finesse of substantially 2 is considered to be non-obvious, since the closest prior art (D1) points in another direction.

The subject-matter of **claim 1**, therefore, involves an inventive step (Article 33(3) PCT).

- 3.4 The same reasoning applies, mutatis mutandis, to the subject-matter of the corresponding independent **claims 7, 24**, which therefore are also considered inventive.
- 3.5 **Claims 1-23** are dependent on **claim 1** (or on **claim 7**) and as such also meet the requirements of the PCT with respect to inventive step. The same holds for method **claims 25-29** that depend on **claim 24**.

CLAIMS

1. An optical wavelength meter (40) for measuring an optical wavelength of an optical beam comprising:
 - a) coarse optical filter means (43) and first optical power measurement means (422) for measuring output of the coarse optical filter means and second optical power measurement means (421) for measuring an unfiltered reference beam for coarse wavelength measurement;
 - b) fine optical filter means comprising first and second periodic optical filters (44, 45) in quadrature having a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first filter coincide with substantially linear ranges between peaks and troughs of the second filter, and third and fourth optical power measurement means (423, 424) for measuring output of the first and second periodic optical filters in quadrature for fine wavelength measurement, respectively;
 - c) beam splitting means (41) for splitting the optical beam between the unfiltered reference beam and the coarse and fine optical filter means;
 - d) synchronized clock signal measurement means for synchronized measurement of the output of the first, second, third and fourth optical power measurement means; and
 - e) processing means for determining the optical wavelength of the optical beam from a predetermined transmissivity-wavelength relationship of the coarse filter and the first and second optical power measurement means for coarse wavelength measurement and from predetermined transmissivity-wavelength relationships of the first and second periodic optical filters and at least one of the third and fourth optical power measurement means for fine wavelength measurement.
2. An optical wavelength meter as claimed in claim 1, wherein the coarse optical filter means comprises a linear spectral filter.

3. An optical wavelength meter as claimed in any of the preceding claims, wherein the coarse optical filter means comprises a dielectric multilayer coating on a glass substrate.
4. An optical wavelength meter as claimed in any of the preceding claims, wherein the periodic optical filters comprise at least one of a Fabry Perot filter, a Fizeau filter, a fibre Bragg grating and a photonic crystal.
5. An optical wavelength meter as claimed in any of the preceding claims, wherein a phase offset between the first and second periodic optical filters in quadrature is tuned by angle, temperature or pressure using a piezoelectric transducer.
6. An optical wavelength meter as claimed in any of the preceding claims, wherein reflectivity of the periodic optical filters is substantially 25%.
7. An optical wavelength meter as claimed in any of claims 1 to 6, wherein the periodic optical filters have a free spectral range of substantially 50 GHz instead of substantially 100 GHz.
8. An optical wavelength meter as claimed in any of the preceding claims, wherein the periodic optical filters are parallel or wedge quartz etalons.
9. An optical wavelength meter as claimed in any of the preceding claims, further comprising calibration filter means and calibration filter output power measuring means.
10. An optical wavelength meter as claimed in claim 9, wherein the calibration filter means comprises an etalon filter.
11. An optical wavelength meter as claimed in claim 10, wherein the etalon filter has precisely set or controllable free spectral range.
12. An optical wavelength meter as claimed in claims 10 or 11, wherein the free spectral range of the etalon filter is controllable and preset by rotation adjustment or temperature.
13. An optical wavelength meter as claimed in any of claims 10 to 12, wherein free spectral range of the calibration etalon filter differs just sufficiently from the free spectral range of the periodic optical filters that the calibration etalon filter is in phase only at top, middle and bottom wavelengths of a range of

measurements of interest to obtain co-incident or Vernier-like maximum power at those wavelengths.

14. An optical wavelength meter as claimed in any of the preceding claims, wherein at least one of the optical power measurement means comprises a photodiode.
15. An optical wavelength meter as claimed in any of the preceding claims, wherein the synchronised clock signal measurement means comprises master module (114) and slave modules (115, 116) to trigger measurement and read output of the optical power measurement means.
16. An optical wavelength meter as claimed in claim 15, wherein the synchronised clock signal measurement means enables 40,000 points on each of a plurality of channels to be read in 2.5 seconds.
17. An optical wavelength meter as claimed in any of the preceding claims, wherein, the synchronised clock signal measurement means enables 1,000 to 10,000 wavelength measurements/second.
18. An optical wavelength meter as claimed in any of the preceding claims, having a precision of substantially 2 picometers or substantially 250 MHz.
19. An optical wavelength meter as claimed in any of the preceding claims, arranged to make wavelength measurements in at least one of optical C-band, optical L-band and optical S-band.
20. An optical wavelength meter as claimed in any of the preceding claims, further comprising temperature control means for stabilising optical components thereof.
21. An optical wavelength meter as claimed in claim 20 wherein the temperature control means comprises a thermistor or thermocouple and fan cooling or Peltier temperature elements.
22. An optical wavelength meter as claimed in any of the preceding claims, adapted for external triggering for synchronisation with external instrumentation.
23. An optical wavelength meter as claimed in any of the preceding claims arranged to measure infrared or visible wavelengths.

24. A method of determining wavelength of an optical beam comprising:
- a) splitting the optical beam into first, second, third and fourth sub-beams;
 - b) presenting the first sub-beam to reference first photodetector means (421);
 - c) presenting the second sub-beam to coarse filter means (43) having an output to second photodetector means (422);
 - d) presenting the third sub-beam to a first fine periodic filter (44) having an output to third photodetector means (423);
 - e) presenting the fourth sub-beam to a second fine periodic filter (45) having an output to fourth photodetector means (424), wherein the first fine periodic filter and the second fine periodic filter are in quadrature and have a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first fine periodic filter coincide with substantially linear ranges between peaks and troughs of the second fine periodic filter;
 - f) using synchronized clock signal measurement means to read outputs from the first, second, third and fourth photodetector means;
 - g) identifying from predetermined transmissivity-wavelength characteristics of the coarse filter means and the first and second photodetector means outputs a limited range of wavelength in which the wavelength of the optical beam lies, to determine from their predetermined transmissivity-wavelength sensitivities which of the first fine filter and the second fine filter has a greater sensitivity to wavelength in that limited range; and
 - h) using predetermined transmissivity-wavelength characteristics of the first or second fine filter having the greater sensitivity in the limited range of wavelength and the corresponding third or fourth photodetector means output, corresponding to the fine filter means having the greater sensitivity, to determine the wavelength of the optical beam.

25. A method as claimed in claim 24, comprising the further steps of:
- a) providing a calibration etalon filter with conventional Airy function transmitting only at a reference wavelength for calibration having a common maximum with the first and second fine periodic filters respectively at a limited number of wavelengths within range;
 - b) providing a broadband light source; and
 - c) calibrating the processed readout from fine periodic filters to the reference wavelength of the calibration etalon filter.
26. A method as claimed in claim 25, wherein step b) alternatively comprises providing a tuneable laser tuned to the reference wavelength.
27. A method as claimed in claim 25, wherein step a) additionally comprises providing a fourth Airy etalon in ratio with the third Airy etalon to provide a common maximum at the limited number of wavelengths for a more defined optical transmitted bandwidth.
28. A method as claimed in any of claims 24 to 27, for measuring infrared or visible wavelengths.
29. A computer program comprising code means for performing all the steps of the method of any of claims 24 to 28 when the program is run on one or more computers.